Northeast Gulf Science

Volume 2
Number 2 *Number 2*

Article 1

12-1978

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DOI: 10.18785/negs.0202.01

Northeast Gulf Science Vol. 2, No. 2, p. 77-97 December 1978

HYPOTHERMAL MORTALITY IN MARINE FISHES OF SOUTH-CENTRAL FLORIDA JANUARY, 1977[1]

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ABSTRACT: Comparable climatic conditions on both coasts of central Florida resulted in cold induced fish mortalities from 19 January to 13 February 1977. Lethal temperatures, the species killed and their relative numbers killed are compared for the Indian River lagoon, Tampa Bay and Sanibel Island estuarine systems. Fifty-six species were killed in the Indian River area, 36 in the Tampa Bay area, while 19 died at Sanibel Island. The higher species mortality in the Indian River lagoon may be attributed to local hydrological and topographical conditions-and a richer ichthyofauna. Cold-induced mortality was noted in both juvenile and adult tropical fishes. Some tropical species appear to be more eurythermic than others as lethal minimum temperatures ranged from 6 to 13 C. Hypothermal stress and mortality were observed in offshore reef fishes.

Prior cold mortality accounts from the literature combined with the current study reveal that a total of 132 fishes have suffered cold mortality in Florida waters.

Florida marine fishes variously affected by low seawater temperatures have been listed by several authors for specific times and locations around the state (Willcox, 1887; Verrill, 1901; Finch, 1917; Storey and Gudger, 1936; Storey, 1937; Miller, 1940; Galloway, 1941; Gunter and Hall, 1963; Rinckey and Saloman, 1964, Snelson, 1978). However, simultaneous observations of mass cold mortality from several regions of the state have never been compared in detail. Some differences and similarities in low water temperature effects can be seen between both coasts of Florida compared here. Concurrent observations were made of fish mortality on the Gulf coast (Sanibel Island and Tampa Bay) and the Atlantic coast (Indian River lagoon). All of these areas are shallow coastal estuaries vulnerable to significant climatic changes.

Temperate and subtemperate estuarine fishes are generally regarded as eurythermic when compared to offshore fish populations and subtropical or

[1]Contribution number 110, Harbor Branch Foundation, Inc., Ft. Pierce, FL.

tropical fishes. However, occasionally environmental extremes may produce extensive mortality in temperate estuarine fishes (Blegvad, 1929; Gunter, 1941, 1945, 1947a, 1947b; Gunter and Hildebrand, 1951; Southward, 1958; Moore, 1976). The estuaries examined in this study are situated within a subtemperate - subtropical transition zone between the Carolinian and Caribbean faunal regions (Briggs, 1974). Both stenothermic tropical Caribbean and eurythermic temperate Carolinian fishes are sympatric within the study areas. In south-central Florida estuaries, those species most sensitive to low temperatures are principally tropical species (Storey, 1937; Briggs, 1974). These species in many cases reach their northern breeding limits in Florida waters (Briggs, 1958, 1974; Robins, 1971; Herrema, 1974; Gilmore, 1977) and become vulnerable to low temperature stress in this portion of their range (Storey, 1937).

Comprehensive water temperature data is lacking in historical accounts of cold-induced fish mortalities in Florida. Detailed air and water temperature records taken during January 1976 and 1977 reveal atmospheric and water temperature trends that may produce hypothermal stress and mortality. It may now be possible to predict the severity of atmospheric cold front effects on the local fish fauna in the regions studied based on combined atmospheric and water temperature data patterns presented below.

METHODS

Air temperatures and wind conditions for the St. Petersburg-Clearwater Airport, Pinellas County, Tampa International Airport, Hillsborough County and the Vero Beach Airport, Indian River County were taken from National Weather Service (NOAA) records.

Indian River seawater temperatures in the Vero Beach area were furnished by the Vero Beach Municipal power plant (intake temperatures). Atlantic surf temperatures at Vero Beach were taken daily at 0700 hr using a field fahrenheit thermometer. Most seawater temperatures other than those monitored remotely were taken using a field Celsius thermometer at a depth of 0.5 to 1.0 m and recorded to the nearest 0.5 C. Atlantic Ocean temperatures at the Florida Power and Light Hutchinson Island nuclear power plant were taken 0.75 m below the surface on a continuous recording Ryan-Peabody thermograph approximately 365 m offshore over a water depth of 6 m. Intake water temperatures were also monitored in the Tampa Bay area at two electric generating plants, Higgins and Bartow, located on Old Tampa Bay (Fig. 1). The National Weather Service, Ruskin, Florida furnished water temperatures for Egmont Key which were taken by the U. S. Coast Guard. The Florida Department of Natural Resources Marine Research Laboratory furnished Gulf of Mexico bottom water temperatures to 64 km off Egmont Key on a transect of 253°.

Tide information for Mullet Key, Clearwater Beach and Bay Aristocrat Village was obtained from the National Ocean Survey, Rockville, Maryland.

Fishes were collected with dip nets, cast nets, drop nets, seine and gill nets or by hand. When fish collections or observations were made, accurate counts of fishes killed were difficult if not impossible in most cases. Therefore, quantitative estimates are based on the simple and generally accepted abundance

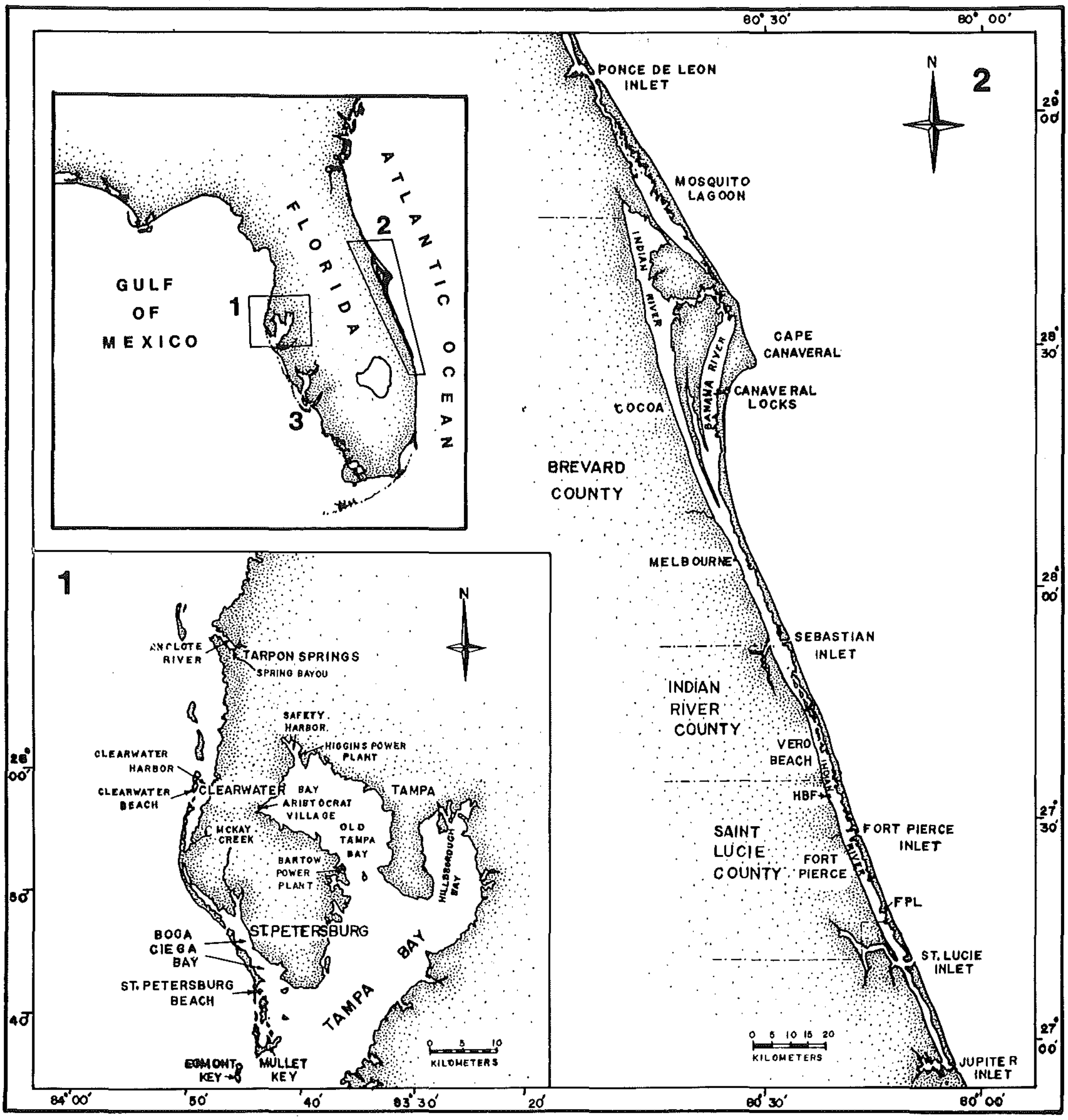

Figure 1. Florida map: inset 1 = Tampa area; 2 = Indian River lagoon; 3 = Sanibel Island (not enlarged). HBF = Harbor Branch Foundation, Inc. ship channel. FPL and Light Corp., Hutchinson Island nuclear power plant.

categories of Starck (1968): Rare = species where three or fewer specimens were observed or collected; Occasional = species observed or collected at irregular intervals; Frequent = species collected on numerous occasions or are taken in a large percentage of collections; Common = species found in virtually every observation or collection; Abundant = common species present in large numbers. Quantitative fish samples in the Indian River lagoon were taken with gill nets, seines, and drop nets following methods described by Gilmore, *et al.* (1978).

All nomenclature follows Bailey, *et al.* (1970) except for the following recent taxonomic changes in which the latter name was preferred: *Diapterus olisthostomus* (Goode and Bean) = *D. auratus* Ranzani (Deckert, 1973); *Harengula pensacolae* (Goode and Bean) = *H. jaguana* Poey (Whitehead, 1973); *Micropogon undulatus* (Linnaeus) = *Micropogonias undulatus* (Linnaeus), *Bairdiella chrysura* (Lacepede) = *Bairdiella chrysoura* (Lacepede) (Choa, 1977).

RESULTS

On 16 and 17 January 1977, an arctic cold front moved over the Florida peninsula (Fig. 2). A significant drop in air temperature occurred within a relatively short period of time. Air temperatures at 0700 hr on 15 January were 17.2 and 20.0 C at the St. Petersburg-Clearwater and Vero Beach airports, respectively, but by the 18th, 0700 hr temperatures were 2.8 and -1.7 C, respectively. On the morning of the 19th a light snow fell over much of Florida and on this and the following three days record low air temperatures occurred over most of the state (Palm Beach Post, February 1977). During 17-23 January strong NW winds were recorded with average velocities of 4.7 m/sec (gusts to 18.2 m/sec) and 3.7 m/sec (gusts to 11.3 m/sec) for Vero Beach and St. Petersburg, respectively. Minimum air temperatures for the month were observed on the 19th at St. Petersburg (1.7 C) and on the 20th at Vero Beach (-3.9 C). Seawater temperatures in the Indian River lagoon (27°32.1'N) fell from 16.0 C on the 17th to 6.0 C on the 19th. The drop in water temperature appeared to follow the drop in air temperature by 24 hours. There was a three day lag between the minimum air temperature and the Atlantic water temperature minimum, as the Atlantic minimum of 13.6C was not reached until the 23rd (27° 21.3'N, 365 m from shore). Seawater temperatures at Egmont Key at the mouth of Tampa Bay were considerably lower than Atlantic temperatures (Fig. 2). Egmont Key seawater temperatures remained below 15.6 C from 25 December 1976 until 26 February 1977 while nearshore Atlantic temperatures did not fall below 15.6 C until 20 January. Atlantic seawater temperatures were influenced by the proximity of the warm Florida Current. It is noteworthy that a comparable warm oceanic current does not occur adjacent to the Tampa Bay area. However, inshore waters on both coasts had a similar temperature pattern although the Indian River lagoon reached lower estuarine water temperature minima than did Old Tampa Bay. Air temperatures at Tampa and Vero Beach

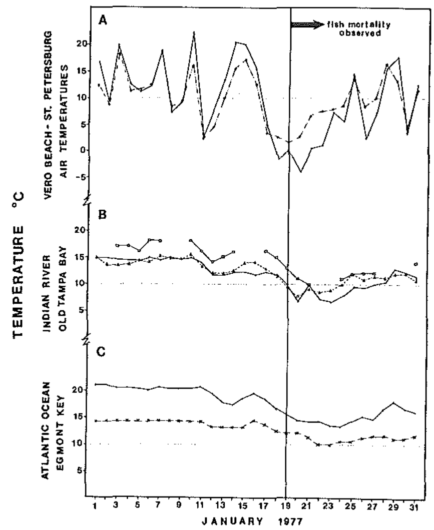

Figure 2. Air and water temperatures (°C) for the Indian River and Tampa Bay study areas, January 1977. A. Air temperatures are from the Vero Beach airport (• —) and the St. Petersburg-Clearwater airport (o — •• —). B. Indian River lagoon water temperatures from the Vero Beach municipal power plant (•—) and the Harbor Branch Foundation ship channel (□——). Old Tampa Bay water temperature means between the Higgins and Bartow power plants (Δ - - -). C. Nearshore Atlantic Hutchinson Island water temperatures (•—) are plotted with Egmont Key water temperatures (x - • -).

airports were generally lower and not as moderate as those at the St. Petersburg-Clearwater Airport. The Gulf of Mexico, Boca Ciega Bay and Old Tampa Bay obviously influenced air temperatures over peninsular St. Petersburg. Strong northwesterly winds associated with the cold front were blowing from the Gulf of Mexico, giving St. Petersburg and Old Tampa Bay higher temperature minimums relative to the other inshore sites monitored on both coasts. These same westerly winds cooled by the Florida land mass brought relatively colder coastal temperatures to the Indian River lagoon and vicinity.

Hypothermal stress in the local fish fauna was not noticed until 19 January on both coasts. (Snelson, 1978, concurs). Massive mortality, predominately of tropical and subtropical species (Table 1), was observed from 20 to 23 January on both the Gulf and Atlantic coasts. The following regional accounts present a more detailed analysis of fish mortality for respective areas of Florida.

INDIAN RIVER LAGOON

This shallow saline lagoon (e.g. salinity range 5 - 55°/₀₀, mean @ 25°/₀₀) extends 253 km along the east central Florida coast from 29°05'N to 26° 58'N. The mean depth of the lagoon is approximately 1.5 m making much of the water column vulnerable to atmospheric climatic conditions. Much of the lagoon is therefore subject to wind driven tidal movements, turbulence, and temperature changes.

After the 17 January cold front moved over the Florida east coast, Indian River lagoon waters appeared to stratify initially as strong cold westerly winds blowing off the mainland cooled and pushed surface waters toward the east shore. Because of the cold westerly winds widespread hypothermal mortality of mangroves (*Rhizophora*, etc.) occurred only on the west shore at this latitude. Lagoon water temperatures along the east shore across from the Harbor Branch Foundation Laboratory (27°32'N) fell from 14.5 to 6.0 C within 24 hours, 18 to 19 January, while surface temperatures along the west shore remained above 13.0 C. During this initial cooling period a deep ship channel (to 4 m depths) on the west bank apparently acted as a thermal refuge (Fig. 2, Harbor Branch Foundation ship channel). However, as water temperatures dropped to 10 C in this channel on the 21st, many fishes that had apparently sought refuge here went into hypothermal shock and suffered massive hypothermal mortality. At this latitude minimum lagoon seawater temperatures varied between 6.0 to 9.0 C until 22 January when temperatures rose to 10 C. On the 24th water surface temperatures (1 m depth) had risen to 11 C within the lagoon.

Because of this prevailing westerly wind direction, hypothermal stress and mortality was first observed in the east side of the lagoon and in mosquito impoundments where little vegetative cover was present and the water was shallow (27°32'N). Fish samples and observations were first made on 19 January when juvenile and small adult *Centropomus undecimalis, Mugil curema, Megalops atlantica, Diapterus auratus, D. plumieri, Eucinostomus gula* and *E. argenteus* began to show hypothermal stress, primary chill coma (Doudoroff, 1942) and death near the east shore of the lagoon. Individuals apparently nearing a chill coma were observed swimming erratically near the surface, some becoming moribund. On 20 January four additional species were

TABLE 1. Fishes killed by low seawater temperatures, 19-24 January 1977. Fish abundance categories follow Starck (1968): R = Rare; O = Occasional; F = Frequent; C = Common; A = Abundant.

Species	Indian River Lagoon	Tampa Bay	Sanibel Island	Other Fla. Mortality Rec. 1887 - 1977*
Carcharhinidae				
Carcharhinus leucas	R	—	—	7,9
Sphyrnidae				
Sphyrna tiburo	—	R	—	9,11
Clupeidae				
Harengula jaguana	O	O	—	6
Opisthonema oglinum	O	—	—	
Sardinella anchovia	R	—	—	
Engraulidae				
Anchoa hepsetus	O	—	—	
Elopidae				
Elops saurus	O	F	R	4, 7, 10, 11, 12
Megalops atlantica	O	O	—	3, 4, 7, 10, 11, 12
Albulidae				
Albula vulpes	O	—	—	5
Ophichthidae				
Mystriophis intertinctus	—	R	O	6, 10, 11
M. mordax	—	—	O	
Bascanichthys teres	—	—	F	
Ariidae				
Arius felis	F	O	R	3, 7, 10, 11
Bagre marinus	O	—	A	7, 10, 11
Batrachoididae				
Opsanus beta	—	R	—	
Opsanus sp.	—	—	O	
Ogcocephalidae				
Ogcocephalus radiatus	—	R	—	11
Hemiramphidae				
Hyporhamphus unifasciatus	O	—	—	10, 11
Belonidae				
Strongylura timucu	O	O	—	
Syngnathidae				
Hippocampus erectus	—	R	—	3, 12
Centropomidae				
Centropomus pectinatus	O	—	—	
C. undecimalis	O	F	—	3, 4, 6, 7, 8, 10, 11
C. sp.	—	—	O	
Serranidae				
Epinephelus itjara	O	R	—	3, 10, 11
E. morio	R	—	—	10, 11
Mycteroperca microlepis	O	—	—	
Rachycentridae				
Rachycentron canadum	—	—	R	
Carangidae				
Caranx hippos	C	C	R	?2, 3, ?5, 6, 7, 10, 11, 12
Caranx crysos	R	—	—	3, 5, 7, 10, 11
Chloroscombrus chrysura	O	—	R	
Trachinotus carolinus	O	—	—	1, 7, 10, 11
T. falcatus	F	O	C	6, 10, 11
Selene vomer	C	O	—	5, 6, 7
Lutjanidae				
Lutjanus analis	O	—	—	3, 5
L. griseus	O	O	—	3, 5, 7, 8, 9, 10, 11
L. synagris	O	—	—	3, 5, 6, 9, 10, 11
Gerreidae				
Diapterus auratus	A	0**	—	4, 7
D. plumieri	C	C	—	6, 7, 8
Eucinostomus argenteus	C	O	—	6, 7
E. gula	C	R	R	6
E. lefroyi	O	—	—	
Gerres cinereus	O	—	—	3
Pomadasyidae				

DOI: 10.18785/negs.0202.01

Table 1 - (cont.)

Species	Indian River Lagoon	Tampa Bay	Sanibel Island	Other Fla. Mortality Rec. 1887 - 1977*
Anisostremus virginicus	R	—	—	3, 9
Haemulon parrai	F	—	—	3, 9
H. plumieri	R	R	—	?2, 3, 9, 10, 11
Sciaenidae				
Micropogonias undulatus	R	—	—	
Sparidae				
Lagodon rhomboides	—	—	R	
Kyphosidae				
Kyphosus sectatrix	—	R	—	
Ephipidae				
Chaetodipterus faber	O	F	O	6, 10, 11
Chaetodontidae				
Pomacanthus arcuatus	—	R	—	3
Pomacanthus sp.	R	—	—	
Chaetodon ocellatus	—	R	—	
Pomacentridae				
Eupomacentrus dorsopunicans	R	—	—	
Cichlidae				
Tilapia sp.	—	O	—	
Labridae				
Lachnolaimus maximus	—	O	—	3
Scaridae				
Scarus sp.	R	—	—	3
Sparisoma rubripinne	R	—	—	
Mugilidae				
Mugil cephalus	O	O	—	?2, ?4, 10, 11
M. curema	C	O	—	?2, ?4, 5, 7, 8, 10, 11
M. trichodon	—	O	R	?2, ?3, ?4, 6
M. gaimardianus	—	—	R	
Sphyraenidae				
Sphyraena barracuda	O	—	—	2, 3, ?5, 8, 9
Uranoscopidae				
Astroscopus y-graecum	—	R	—	
Gobiidae				
Lophogobius cyprinoides	R	—	—	
Acanthuridae				
Acanthurus bahianus	R	—	—	
A. chirurgus	R	—	—	
Scombridae				
Scomberomorus maculatus	O	—	—	7, 10, 11
Stromateidae				
Peprilus burti	—	R	—	
Soleidae				
Achirus fasciatus	—	—	O	
Monacanthidae				
Aluterus schoepfi	O	R	R	
Monacanthus hispidus	F	R	—	3, 5, 6, 7
Ostraciidae				
Lactophrys quadricornis	O	C	O	6, 10, 11, 12
L. trigonus	F	—	—	3
Tetraodontidae				
Sphoeroides nephelus	F	O	R	7
S. spengleri	F	—	—	3, 7, 10, 11
S. testudineus	O	—	—	
Diodontidae				
Chilomycterus schoepfi	O	C	R	6, 7, 10, 11

*Previous mortality records: 1 = Evermann and Bean (1897), 2 = Finch (1917), 3 = Galloway (1941), 4 = Gunter and Hall (1963), 5 = Miller (1940), 6 = Rinckey and Saloman (1964), 9 = Starck and Schroeder (1970), 10 = Storey (1937), 11 = Storey and Gudger (1936), 12 = Willcox (1887). A question marker precedes the author reference number if the correct species is not certain from the reference.
**= New Florida-Gulf coastal record.

seen dead on the east bank of the lagoon, *Mugil cephalus, Trachinotus carolinus, Hyporhamphus unifasciatus* and *Arius felis.* Large numbers (70+) of tarpon, *Megalops atlantica,* that were swimming sluggishly and showing obvious hypothermal stress on the 19th, were found dead on the 20th in an east bank impoundment. In the east bank mosquito impoundment at Jack Island State Park (St. Lucie County), 103 tarpon were recorded dead, the only additional species killed being *Diapterus* sp. and *Mugil* sp. (Ranger A. Hoffacker, personal com.)

By 21 January water near the west bank of the lagoon had cooled to 8-10 C to depths of 4 m in the channels and deeper portions of the lagoon. Fifty species (Table 1) and thousands of individuals that had apparently sought refuge in these deeper waters subsequently went into hypothermal shock. Many fish continued to die on the 22nd and 23rd of January. On 22 January fishermen dipped hundreds of *Trachinotus carolinus* and *T. falcata* from the Harbor Branch Foundation ship channel. These were in martketable condition, mostly alive but obviously suffering from hypothermal stress. As the air temperature reached its maximum (15 C) on the 22nd, the pompano were not as readily caught. From 24 January to 4 February bloated carcasses of dead fishes floated to the surface within the lagoon, indicating that many dead fishes had gone to the bottom and were not accounted for during the preceding week. As late as 4 February with lagoon seawater temperatures at 14 C, fishes (e.g. mostly *Diapterus auratus* and *Centropomus undecimalis*) were observed swimming slowly head up at the surface. Some dead specimens appeared to be relatively fresh. The majority of these observations were made in the Indian River lagoon in St. Lucie, Indian River, and Brevard counties as far north as 28°40'N and south to 27°20'N. Concurrent hypothermal fish mortality observations were made in the northern portion of the Indian River, Banana River and Mosquito lagoons by Snelson (1978).

Previous accounts of extensive hypothermal fish mortalities have shown adult deaths to greatly surpass any juvenile mortality observed (Gunter, 1938, 1941, 1947). However, in the Indian River lagoon both juveniles and adults of a number of species died due to hypothermal stress, most notably, the mojarras and *Mugil curema. Diapterus auratus* of all sizes were killed in large numbers. In a finger canal on the east shore of the lagoon (Brevard County, 28°03'N) 169 *D. plumieri* were found dead. Of the 144 measured, 40 (28%) were below 100 mm in standard length and as small as 55 mm. Juvenile (i.e. <125 mm SL) *Elops saurus, Chaetodipterus faber, Caranx hippos, Bagre marinus, Mugil curema, Haemulon parrai, Trachinotus falcata, Lutjanus griseus, L. synagris, L. analis,* and *Albula vulpes* contributed from a portion to up to 100% of the mortality, depending on the species and location. Only juveniles of *Albula vulpes, Haemulon parrai, Lutjanus synagris* and *L. analis* were killed. Many juvenile and adult *Eucinostomus gula* and *E. argenteus* were killed. In many instances adults were more readily seen and observations indicated they suffered greater mortality than juveniles.

Dead fishes were not seen on the Atlantic beaches until 22 January. On this date dead *Sparisoma rubripinne, Scarus* sp., *Diapterus auratus, Haemulon plumieri, Anisostremus virginicus, Eupomacentrus dorsopunicans, Poma-*

canthus sp., *Acanthurus bahianus,* and *Acanthurus chirurgus* were found on the beach (Indian River and St. Lucie Counties). As most all of these species are tropical primary reef forms found in shallow waters, some hypothermal mortality had apparently occurred on the inshore Atlantic reef. The minimum water temperature on these reefs is not known, but surf temperatures where some of the dead reef fishes were beached reached a minimum of 11.1 C on 23 January. Direct observations of reef fishes were not made until the first week of February when SCUBA dives were made on shallow Atlantic reef structures (3-7 m depths) within the study area. These observations demonstrated that a number of reef species survived the cold period (e.g. *Eupomacentrus variabilis, Holacanthus bermudensis, Labrisomus nuchipinnis*).

Differential thermal tolerance was demonstrated by several species of fishes enclosed in an aquaculture pond 1.0 m deep located at the Harbor Branch Foundation laboratory. The pond contained the following fish species on 19 January: *Cynoscion nebulosus, C. regalis, Pomatomus saltatrix, Trachinotus carolinus, Centropomus undecimalis, Scomberomorus maculatus* and *Mugil cephalus.* The four latter species died when pond temperatures reached 6 C on 19 January. The three former species survived the entire cold period. This observation demonstrates the differential thermal tolerances of these species. Similar observations were made of open lagoon fish populations. *Cynoscion nebulosus, C. regalis* and *C. nothus* and *Pomatomus saltatrix* were commonly caught in "good condition" by lagoon sport and commercial fishermen before the 20th and after the 27th, occasionally between these two dates. None of these latter species were observed to suffer hypothermal stress. Differential mortality was also seen among four tropical species which commonly occur within the study area throughout the year, *Strongylura notata, S. timucu, Eupomacentrus variabilis* and *E. dorsopunicans.* Both *S. notata* and *E. variabilis* occur in higher numbers than their congeneric species. Hypothermal mortality was only observed in *S. timucu* and *E. dorsopunicans* indicating that not only do they occur in fewer numbers but they are possibly more sensitive to hypothermal stress. Snelson (1978), however, observed only *S. notata* in the northern portion of the Indian River lagoon system where it was "killed or stunned in small to moderate numbers."

As an extensive ecological survey was underway those fishes present in a comparatively "normal" condition during the "cold-kill" period were collected using rod and reel, gill, seine and drop nets. Of the species observed killed in Table 1 the following specimens were collected alive and in "good condition": 13 lethargic *Diapterus auratus,* 50 *Eucinostomus gula,* 3 *E. argenteus,* 1 *Elops saurus* leptocephalus and 2421 juvenile *Mugil cephalus.* In addition to these, the following species were collected and apparently suffered no hypothermal mortality:

Abundant
- *Lagodon rhomboides*
- *Gobionellus boleosoma*

Common
- *Brevoortia smithi*
- *Pomatomus saltatrix*
- *Cynoscion nebulosus*
- *C. nothus*
- *C. regalis*
- *Sciaenops ocellata*
- *Trichiurus lepturus*
- *Gobiosoma robustum*

Frequent
Menidia peninsulae
Syngnathus scovelli
Occasional
Floridichthys carpio
Fundulus similis
Bairdiella chrysoura
Pogonias chromis
Symphurus plagiusa
Rare
Anguilla rostrata
Urophycis floridanus
Syngnathus louisianae
Archosargus probatocephalus
Paralichthys albigutta

From the data presented it appears that lethal thermal minima for the dead fishes observed were between 6.0 and 15.0 C. However, observations made during the prior year, 1976, tend to indicate the upper minimum in this range may be nearer 13.0 C for the tropical fishes that suffered hypothermal mortality in the Indian River lagoon (the upper minimum is probably less than 12 C in the Tampa Bay area based on January 1977 observations below). During January 1976 (21st - 24th) an incidence of hypothermal shock and some mortality was recorded in the Indian River lagoon. Surface water temperatures within the Harbor Branch Foundation ship channel (depth 3-4 m) had gone below 15 C on the 19th following a cold front (0.0 C air temperature minimum) on the 18th. Another cold front passed between the 21st and the 22nd and air temperatures reached 5.0 C on the 23rd. In the ship channel large numbers of dead *Selene vomer, Diapterus auratus* and *Lutjanus griseus* were observed on the 22nd and 23rd with surface water temperatures at 13 to 14 C. Some of the former species were swimming erratically at the surface, apparently preceding hypothermal shock. Reports were obtained of *Centropomus undecimalis* swimming erratically at the surface but no mortality was seen in this species. No fish mortality was noted other than in the ship channel although other locations within the lagoon were investigated. When comparing this minor cold kill to the 1977 mortality, it appears that some tropical fishes within the Indian River lagoon were able to tolerate a "temporary" surface water temperature depression to 13 C for 24 hours and 14-14.5 C for 96-144 hours. *Haemulon parrai, Sphyraena barracuda* and *Mugil curema*, all tropical species, were observed present and swimming normally within the ship channel and were apparently not affected to the point of hypothermal shock at this location. Ship channel surface temperatures did not go below 13 C in 1976 as they did in 1977, and air temperatures were not as low, nor did they stay low for long periods of time. The cold front passing on 17-18 January 1976 began to lower channel water temperatures and the second front 72 hours later lowered temperatures to a lethal 13 C for the three species killed.

A total of fifty-six fish species suffered cold mortality within the Indian River study region, most of which have a tropical center of distribution (Briggs, 1958, 1974; Robins, 1971; Herrema, 1974; Gilmore, 1977). The most abundant fishes killed in the Indian River lagoon from 28°40'N to 27°20'N were *Diapterus auratus, Caranx hippos, Selene vomer* and *Trachinotus falcatus* all of which have a Caribbean center of distribution and may be considered tropical.

TAMPA BAY AREA

On 25 December 1976, water temperatures monitored by the U. S. Coast Guard at Egmont Key fell below 15.6 C and remained so until 26 February 1977.

Figure 2 summarizes physical conditions during passage of the arctic cold front through the Tampa Bay area on 17-23 January. Wind velocities fluctuated but remained from 310-350° direction (Fig. 3). Tidal levels were less than predicted due to strong winds, allowing shallow bay waters to become wind mixed and chilled. Water temperature monitored by three Tampa Bay area electric power plants reached a minimum 12-16 hours after the coldest air temperature (0 C) was recorded.

At 1900 hours EST on 19 January 1977, several dead *Trachinotus falcatus* and *Diapterus auratus* were observed along St. Petersburg Beach where the surf water temperature was 8.1 C. These mortalities indicated that inshore waters had already reached lethal thermal thresholds for some fish species. These *D. auratus* specimens were the first re-

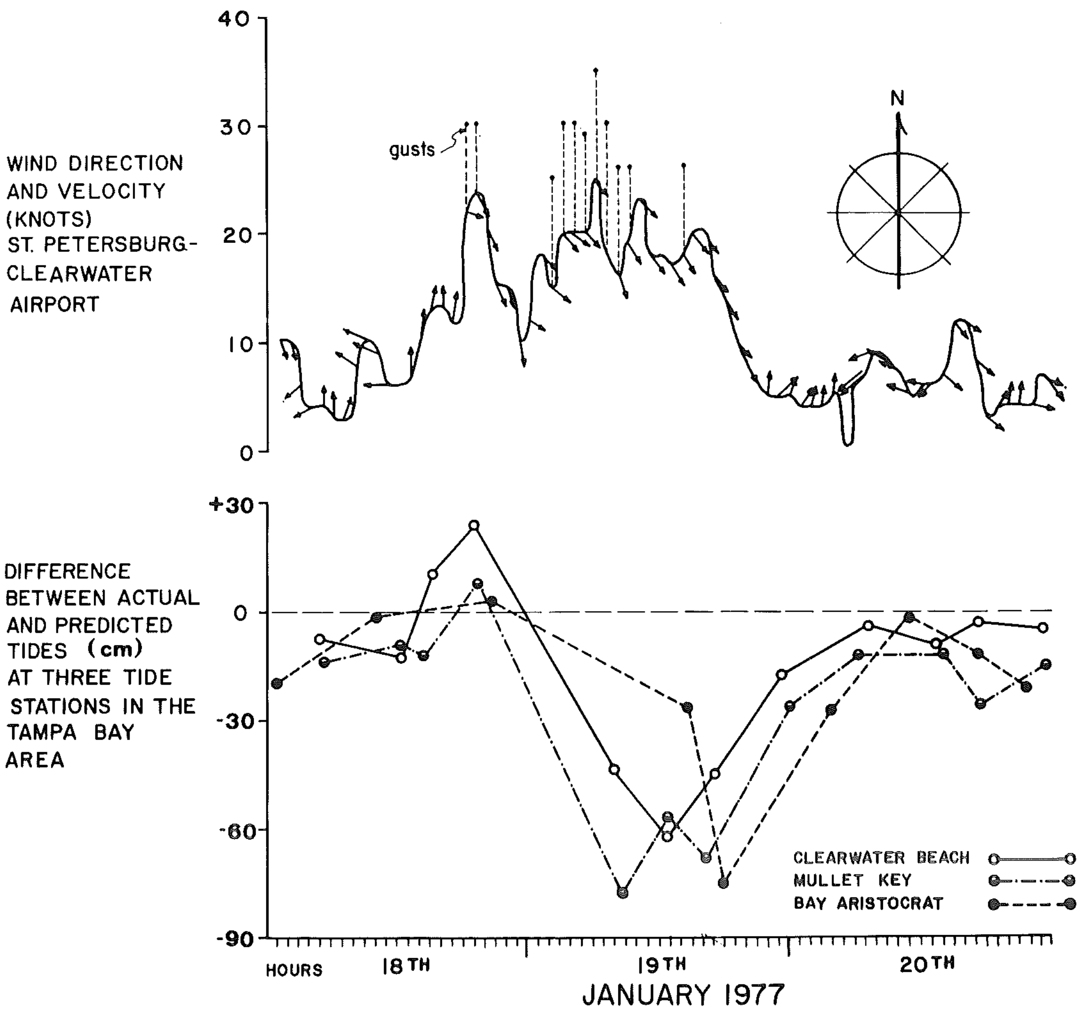

Figure 3. A. Wind direction and velocity (knots) recorded at St. Petersburg-Clearwater Airport, 18-20 January. 1977. B. Difference between actual and predicted tides at three tide stations in the Tampa Bay area, 18-20 January 1977.

cords for this tropical species from the Florida Gulf coast.

Additional observations on 19 January at McKay Creek, a tidal stream flowing into the southern reaches of Clearwater Harbor, provided only one recorded mortality, *Hippocampus erectus*. However, six other species were experiencing hypothermal stress at water temperatures ranging from 6.7 to 7.7 C. *Mugil curema*, *Diapterus plumieri, Harengula jaguana,* and *Eucinostomus argenteus* were lying on their sides or belly-up and exhibited feeble swimming attempts only when probed. Other *M. curema* and a single *Centropomus undecimalis* (885 mm TL) were observed swimming slowly near the surface. Disoriented *Caranx hippos* swam in circles with their heads breaking the water surface similar to behavior described for centropomids and gerreids in the Indian River lagoon. These species were apparently approaching primary chill coma and were found dead by fishermen the following morning.

From 0230 to 0330 hours on 20 January, water temperatures in Boca Ciega Bay at Pinellas Bayway ranged from a near surface reading of 6.6 C (15 cm depth) to 9.2 C (3-4 m depth). Dead fishes included two *Lactophrys quadricornis* and a single *Kyphosus sectatrix*. Individual specimens of *Centropomus undecimalis* (975 mm TL) and a *L. quadricornis* were alive but stranded in shallow water.

Dead *Elops saurus* were observed on 21 January at Memorial Causeway in Clearwater (1404 specimens/1.3 km) where the water temperature was 10.5 C. In contrast, on 23 January this species appeared unstressed in Spring Bayou in Tarpon Springs where the water temperature was 15.3 C. The higher water temperature in Spring Bayou is due to a relatively warm freshwater spring discharge (Wetterhall 1965) which provides a thermal refuge for these fish.

On 26 January water temperatures ranged from 12.8 to 13.0 C in McKay Creek, Boca Ciega Bay (Maximo Moorings) and lower Tampa Bay (Whistler Yacht Basin). *Mugil* sp. (approx. 200 mm TL), *Tilapia* sp. and *Diapterus plumieri* swam lethargically near seawalls. Disoriented *Mugil* sp., *Elops saurus* and *Caranx hippos* swam erratically at the surface and occasionally collided with pilings or seawalls. Wounds, presumably caused by mechanical abrasion, were evident on these fishes.

Air temperature fell to 3.3 C at Albert Whitted Airport in St. Petersburg on 30 January; Tampa Bay waters were sufficiently chilled to cause further mass mortalities in *Mugil* spp., *Lactophrys quadricornis, Centropomus undecimalis* and *Chilomycterus schoepfi* at Mullet Key.

Predation as a secondary effect of hypothermal stress most likely plays a significant role in the total number of fish mortalities. Moss (1973) noted predation by double-crested cormorants, *Phalacrocorax auritus,* on *Monacanthus hispidus* and *Aluterus schoepfi* during periods of low temperature in a New England estuary. A similar incident occurred in St. Petersburg at Frenchman Creek on 23 January where a double-crested cormorant was observed eating small *Mugil* sp. too lethargic to evade capture. On another occasion a single *Centropomus undecimalis* was noted to consume a mojarra experiencing equilibrium problems.

Storey (1937) stated that *C. undecimalis* was consistently harmed by freezes at Sanibel Island, Florida; Marshall (1958) also noted their vulnerability to cold. However, during January lethargic *C. undecimalis* that had not completely succumbed to low temperatures, were highly visible near seawalls. Capture employing cast nets, snatchhooks and spears was common in both the Tampa Bay and Indian River areas.

In the Tampa Bay area *C. undecimalis, Caranx hippos, Megalops atlantica, Elops saurus, Mugil* sp. and *Diapterus plumieri* were observed to crowd into shallow water in marinas and tidal creeks. In the upper reaches of McKay Creek, where water depth at high tide does not exceed 1 m, unusually large numbers of *Caranx hippos* and *Diapterus plumieri* were discovered during the coldest periods of January. Observations in the Tampa Bay area seem to indicate that protected marinas, as well as spring fed tidal creeks, served as shallow water refuges, possibly subject to solar warming.

A total of thirty-six fish species suffered cold mortality in the Tampa Bay study area during January 1977. Of the 16 fish species recorded as affected by low water temperatures in Tampa Bay during 1962 (Rinckey and Saloman 1964), only four species were not observed in the present study: *Lutjanus synagris, Synodus foetens, Microgobius gulosus, Diodon* sp. The dominant fishes killed in 1962 and 1977 were *Caranx hippos* and *Diapterus plumieri.*

Underwater observations of fishes associated with offshore reef formations were made from 13 February to 30 June, immediately following the described inshore fish mortalities. Surface and bottom seawater temperatures in the Gulf of Mexico were taken during two hydrographic transects made on 25 January and 15 February up to 64 km due west of Egmont Key (Fig. 4). Bottom waters 8-32 km offshore in 10-25 m depths reached temperature minima on 25 January (11.6-12.7 C). Further offshore, 48 to 64 km, 30-40 m depths, bottom water temperatures reached temperature minima on 15 February (13.0-13.6 C). During a SCUBA dive on 13 February made on offshore ledges 18.3 m deep (27°29'N, 83°01'W) decomposing remains of several *Lutjanus griseus* were found. Live individuals of *L. griseus* and *Lachnolaimus maximus* showed evidence of lateral scale loss and eroded fins. Similar conditions were noted for these same species inhabiting ledges 39.6 m deep (27°24'N, 83°22'W). This latter observation tends to indicate that even offshore reef fishes at depths of 39 m were not protected from hypothermal stress in the Gulf of Mexico during February 1977. Scale loss was evident on these same species at these reefs until June. An attempt to isolate opportunistic pathogens from an affected *L. griseus* was unsuccessful; a necropsy revealed no internal pathological manifestations. Scale loss and eroded fins were initially assumed to be a result of buffeting of *Lutjanus griseus* and *Lachnolaimus maximus* against limestone

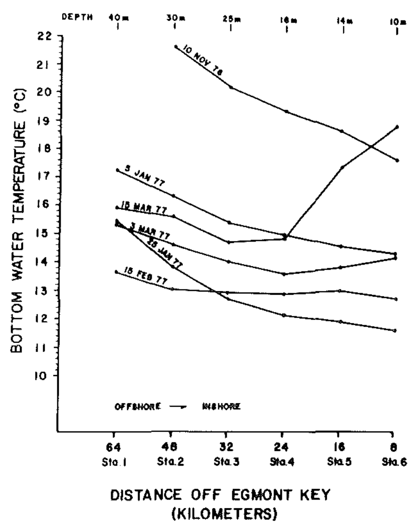

Figure 4. Gulf of Mexico bottom water temperatures to 64 km off Egmont Key on a transect of 253°.

ledges as they attempted to maintain in turbulent waters. However, similar conditions were observed in these fishes at a depth of 39.6 m where turbulence would presumably be insignificant. During February and early March *Mycteroperca microlepis* and *Epinephelus morio* were found under deeply undercut ledges. Lethargic individuals of *Balistes capriscus* and *Haemulon plumieri* could be removed from their hiding places by hand. Species appearing relatively active during the cold included: *Serranus subligarius, Centropristis* sp., *Diplectrum formosum, Halichoeres bivittatus* and others.

The total number of offshore species of fish adversely affected is unknown. However, the chance sighting of dead *Pomacanthus arcuatus* and *Chaetodon ocellatus* floating at the surface 28 km SW of Egmont Key on 23 January (G. B. Smith, personal com.) indicates that more species were killed than those listed here.

SANIBEL ISLAND

Sanibel Island west of Ft. Myers, Florida, is bordered by the Gulf of Mexico to the west and south and by Pine Island Sound to the northeast and San Carlos Bay to the southeast. It is connected to the mainland by a three-bridge causeway (4.5 km long) with two major fill areas (total 2 km). Observations related to this report were from ca. 26°25' - 29'N, 82°02'W.

Four paired temperature records were made with a handheld thermometer:

Date	EST	Air °C	Surf °C
Jan. 21	0720	12.2	11.1
Jan. 22	0830	8.3	10.6
Jan. 22	0930	12.2	12.8
Jan. 22	1300	14.4	13.6

Fish mortality was first recorded on Sanibel Island at 1030 EST, January 20. Hundreds of *Bagre marinus* and several *Trachinotus falcatus* were dead along the two fill areas of the causeway. Observations and collections of representative dead fishes were made along the causeway on the afternoon of January 20 and the morning of January 21 and along the southern Gulf beach on the afternoon of January 21. Nineteen fish species were recorded during the period: ca. 5,000 to 10,000 *Bagre marinus,* 47 *Trachinotus falcatus,* five species with two to seven individuals each, and 12 species represented by a single specimen each (Table 1). In addition, dead *Centropomus* sp. were reported in some island canals.

Three of the 47 *Trachinotus falcatus* recorded were the only fish living and showing hypothermal stress seen in the survey. These were slowly and erratically swimming in the surf during January 20 and 21. Some stressed *Centropomus* sp. were reported from some canals.

Several unexpected occurrences and aspects were noted for the dead species observed. A size-selected sample of *Bagre marinus* ranged 256 to 455 mm FL (fork length) and 228 to 1650 gm RD (round weight) while the single *Arius felis* was 220 mm FL and 127 RD. The size range of *Trachinotus falcatus* was appreciable, ranging from 160 to 462 mm FL and 107 to 2142 gm RD. Only two specimens of *Mugil* were found and these were within a 25 meter distance on the causeway and were different species (*Mugil trichodon* 262 mm FL and 210 gm, *Mugil gaimardianus* 305 mm FL and 440 gm).

DISCUSSION

Stenothermic tropical and subtropical fishes suffered the greatest mortality during January 1977. These species were almost entirely typical estuarine and shallow coastal zone inhabitants. Those species killed that belong to large, widely distributed neritic families (predominantly found offshore) with species occurring throughout both tropical and temperate regions were either inshore representatives of their family (e.g. *Carcharhinus leucas* and *Hyporhamphus unifasciatus*) and/or stenothermic representatives of their family (e.g. *Harengula jaguana*).

A combination of physical conditions produced the extensive fish mortality observed in the study areas: 1) the passage of the cold front was sudden, 2) water temperature minima were very low (to 6.0 C) and 3) water temperatures remained low (6.0 - 12.0 C) for five to six days. Deeper water within the estuaries was not an adequate haven as high northwesterly winds associated with the Arctic front caused extensive water turnover and an adequate protective thermocline did not develop. Subsequently, the entire water column to depths of 4 m cooled within 48 hours to 72 hours, producing extensive mortality in these potential refuges. A similar deep water "refuge-death trap" phenomenon has been noted by other authors (Tabb 1966; Moore 1976; Snelson 1978). Lower than average tides partially induced by strong northwesterly winds increased the severity of thermal conditions in the Tampa Bay area. In some cases, shallow protected waters and creeks fed by thermal springs (e.g. Spring Bayou, Tarpon Springs) did not cool to lethal temperatures and some fishes were able to live through the cold period in these areas.

Fishes with limited mobility were greatly affected. Plectognath fishes (puffers, Tetraodontidae and Diodontidae; boxfishes, Ostraciidae; filefishes, Monacanthidae; and triggerfishes, Balistidae) are notable for their tropical affinity, poor mobility and high occurrence in hypothermal fish kills. They could not escape the rapidly cooling shallow waters as readily as other species, and subsequently their bodies were commonly found along lagoon beaches.

Many cryptic and diminutive tropical blennies and gobies were probably also killed but were not as readily observed. Of these latter two families only two gobies, *Lophogobius cyprinoides* and *Microgobious gulosus*, have been observed in winter mortalities (Rinckey and Saloman 1964). Adequate observations of very small species (adults 25 mm or less SL) and larvae (<20 mm) of larger species have yet to be made.

Most observations made by Storey (1937) are in agreement with our findings. However, her placement of the pompano, *Trachinotus carolinus* and Spanish mackerel, *Scomberomorus maculatus* on the "seldom hurt" list does not agree with observations made in the Indian River lagoon. Both species are well known for their narrow thermal limits (Berry and Iversen 1966; Klima 1959) and have suffered hypothermal mortality along the Florida east coast (Evermann and Bean 1897; Snelson 1978). Since cold mortality in these species was only noted within the confines of the Indian River lagoon, it is possible that these mobile species were not able to make it to the nearest ocean access before they suffered hypothermal stress and subsequently lapsed into a primary chill coma. Ready access to warmer Atlantic Ocean or Gulf waters may prevent mortality in *T. carolinus* and *S. maculatus* in other areas of Florida.

January 1977 temperature data indicate that seawater temperatures were generally lower in Gulf coastal areas of the same latitude than they were on the Atlantic coast (Fig. 2). Arctic cold fronts coming from the northwest, shallower offshore Gulf waters, and the Florida Current along the Atlantic coast can help explain this neritic water temperature phenomenon. Yet inshore estuarine waters had a similar trend on both coasts, with Indian River lagoon water revealing a lower minimum due to strong westerly winds cooled further by the Florida land mass.

Fewer fishes were observed to suffer mortality in the Tampa Bay area than in the Indian River lagoon (36 versus 56). Fewer fish species occur in the Tampa Bay area (27°00'-28°00'N, 82°25'-84°30'W), (approximately 370 species, Springer and Woodburn 1960; Moe and Martin 1964; Powell *et al.* 1972; Smith 1976) than in the Indian River area (664 species, Gilmore 1977, and unpublished data). Those tropical and eurythermic tropical species that do occur in the Tampa Bay area appear to make a seasonal migration offshore during the colder winter months (Springer and Woodburn ibid). In the Indian River lagoon many tropical forms appear to remain within the lagoon although in fewer numbers as indicated by winter seine captures (Gilmore *et al.* 1975, 1976, unpublished Harbor Branch Foundation Annual Report) and the recent fish kill. The topography of the Tampa Bay area permits ready access from inshore bays to the Gulf of Mexico, and this access is apparently utilized by many stenothermic warm water species in their annual offshore migration as coastal waters cool (Springer and Woodburn 1960). For 253 km along the Florida central east coast there are only five small inlets that continually give access to the open Atlantic Ocean from the Indian River lagoon system. Warm stenothermic fishes in the Tampa Bay area may be able to escape colder temperatures more readily than those in the Indian River lagoon. They may also be better conditioned to cold temperature response as seasonal water temperatures decrease earlier and apparently more gradually than on the central east coast (Fig. 2). These coastal differences in temperature regimes may account for the absence of a number of tropical species from the Tampa Bay area, which are not uncommon in the Indian River region (Table 2). Table 2 is a partial list of the tropical species not shared by both study areas and only the more common forms of the Indian River lagoon system are listed (Gilmore 1977). A number of these fishes occur in the northern Gulf along the Florida

TABLE 2. Sample of tropical fishes commonly occurring in shallow coastal waters of the Indian River study area but not recorded from the Tampa Bay area.

SPECIES	ABUNDANCE	OBSERVED COLD EFFECT, 1977
Scorpaenidae		
Scorpaena plumieri	common	?
Centropomidae		
Centropomus pectinatus	frequent	killed
Apogonidae		
Apogon maculatus	common	?
Carangidae		
Caranx ruber	common	?
Lutjanidae		
Lutjanus analis	common	killed
L. jocu	common	?
Gerreidae		
Eucinostomus lefroyi	common	killed
Pomadasyidae		
Anisostremus surinamensis	common	?
Haemulon parrai	common	killed
Sciaenidae		
Bairdiella sanctaeluciae	common	?
Umbrina coroides	common	?
Pomacentridae		
Eupomacentrus dorsopunicans	common	killed
Labridae		
Halichoeres maculipinna	common	?
Thalassoma bifasciatum	common	?
Scaridae		
Sparisoma chrysopterum	common	?
S. rubripinne	common	killed
Clinidae		
Labrisomus nuchipinnis	abundant	?
Malacoctenus triangulatus	common	?
Blenniidae		
Blennius cristatus	common	?
Hypleurochilus bermudensis	common	?
Gobiidae		
Coryphopterus dicrus	frequent	?
Gobionellus smaragdus	common	?
G. stigmaturus	common	?
Lophogobius cyprinoides	common	killed
Acanthuridae		
Acanthurus chirurgus	common	killed
Bothidae		
Citharichthys spilopterus	common	?
Tetraodontidae		
Sphoeroides testudineus	common	killed

coast (Hastings, 1972; G. Smith, 1974; Walls, 1975) primarily during the warmer months as juveniles and in some cases as adults also. It should also be noted that until this study, *Diapterus auratus*, which is common to abundant in the Indian River lagoon, suffering the highest hypothermal mortality, was not recorded from the Florida west coast.

Fewer species were seen in the hypothermal mortality at Sanibel Island than in the other study areas. Other observers in the Sanibel Island area also indicated a relatively low mortality occurred (T. H. Fraser, Environmental Quality Lab.; Fla. Marine Patrol, personal com.). The minimum recorded surf temperature was 10.6 C on 22 January, two to three degrees higher than minimums on the same day at Tampa Bay and the Indian River lagoon. Besides having higher water temperatures, the Sanibel study area was at a location accessable to the more moderate open waters of the Gulf of Mexico. These observations indicate that the Sanibel Island area did not have as severe mortality as the Tampa Bay area and Indian River areas.

Unpublished data on spawning periods and seasonal juvenile abundance within the Indian River lagoon indicate that juveniles of many species are not common or present during the colder winter months (Gilmore, *et al.*, 1976, unpublished Harbor Branch Foundation Annual Report). However, there are a few tropical species that are present as juveniles during the winter (e.g. *Diapterus auratus, Haemulon parrai,* etc.). Because large numbers of juveniles and adults of a number of these tropical species (e.g. *D. auratus, E. saurus, H. parrai*) suffered hypothermal mortality it can be assumed that tropical species are temperature sensitive at most stages of development. Gunter (1938, 1941, 1947) has indicated that juvenile fishes may withstand lower water temperature than adults of the same species. This may be true on the Texas coast as many juvenile sciaenids, atherinids, etc. (subtemperate-Carolinian fauna) may be found in shallow coastal waters during the colder months of the year (Gunter, 1945; Gallaway and Strawn, 1974). However, the southern half of the Indian River lagoon has a depauperate sciaenid population (excluding *Cynoscion nebulosus* and *Bairdiella chrysoura* which spawn during the warmer months) and there is no large influx of juvenile sciaenids (e.g., *Micropogonias undulatus* and *Leiostomus xanthurus*) during the winter-early spring comparable with that seen along the Texas coast (Gunter, 1945; Gallaway and Strawn, 1974). Two notable exceptions to the juvenile cold mortality were observed in the monthly seine catch within the Indian River during January, 1977. Large numbers of juvenile (10-25 mm SL) *Mugil cephalus*, which has a circumtropical-warm temperate distribution (Moore, 1976), and *Lagodon rhomboides*, predominately a warm temperate Carolinian species (Caldwell, 1957), were captured in active schools at temperatures as low as 10.0 C during and after the observed period of maximum cold mortality. However, adult *Mugil cephalus* did die during the period of maximum cold mortality. Although no juvenile croaker, *Micropogonias undulatus*, were seen, several adults of this species were found dead at two lagoon stations. These data suggest that stenothermic tropical and subtropical fishes are cold sensitive at all stages of development while subtemperate Carolinian forms are relatively eurythermic as juveniles. Subtemperate Carolinian adults are somewhat less eurythermic than their juveniles and are capable of making extensive migrations to warmer water (Gunter, 1945; Springer and Woodburn, 1960).

Variable hypothermal mortality of tropical fishes in the Indian River lagoon in both January 1976 and 1977 demonstrates differential low lethal temperatures in these fishes. Observed lethal temperatures ranged from 6 to 13 C. *Diapterus auratus, Selene vomer* and *Strongylura timucu,* etc. were observed dead at the upper end of the lethal temperature range while *Strongylura notata, Haemulon parrai* and *Centropomus undecimalis*, etc. died nearer the low end of the observed lethal temperature range. This differential death of tropical fishes over a range of lethal temperatures has also been observed by Graham (1971, 1972) in controlled laboratory experiments. His lower lethal temperature range was 8-13 C using various tropical species from Panamanian waters. These observations demonstrate that some tropical fishes are more eurythermic than others.

In addition to the 77 species affected by cold in January 1977, 55 other fishes have been recorded in previous publications as suffering mortality during periods of extreme cold in Florida (Table 3). Therefore, a total of 132 fish species have suffered cold mortality in Florida waters. The vast majority of these fishes are tropical and subtropical species. If more extensive observations were made of hypothermal mortality in shallow water reef fishes, the comprehensive mortality list for Florida waters would undoubtedly be longer.

TABLE 3. Fishes previously recorded as killed by cold in Florida but not recorded by the authors during the January 1977 freeze. Author code numbers follow Table 1 with one addition: 13 = Tabb, 1958.

SPECIES'	AUTHOR
Carcharhinidae	
Carcharhinus sp.	11
Rhizoprionodon terraenovae	11
Sphyrnidae	
Sphyrna (zygaena)?	11
Clupeidae	
Brevoortia smithi	7*
Synodontidae	
Synodus foetens	6, 10, 11
Batrachoididae	
Opsanus tau	10, 11
Antennariidae	
Antennarius ocellatus	3
Hemiramphidae	
Chriodorus atherinoides	3
Hemiramphus brasiliensis	3
Belonidae	
Strongylura notata	7, 10, 11
Tylosaurus crocodilus	3
Serranidae	
Epinephelus striatus	3
Diplectrum formosum	3
Mycteroperca bonaci	3, 10, 11
Pomatomidae	
Pomatomus saltatrix	11
Echeneidae	
Echeneis naucrates	7, 11, 10 (possibly *E. neucratoides*)
Carangidae	
Oligoplites saurus	10, 11
Seriola sp.	10, 11
Caranx latus	8
Lutjanidae	
Lutjanus apodus	3, 9
L. jocu	9
Ocyurus chrysurus	3, 9
Pomadasyidae	
Haemulon parrai	3
H. aurolineatum	3
H. flavolineatum	3
H. macrostomum	3
H. striatum	3
Orthopristis chrysoptera	10, 11
Sparidae	
Archosargus probatocephalus	11, 12
A. rhomboidalis	5
Calamus sp.	5
Lagodon rhomboides	7, 9, 11
Sciaenidae	
Bairdiella chrysura	7
Cynoscion nebulosus	7*, 11, 12, 13
Equetus acuminatus	3
Leiostomus xanthurus	7
Menticirrhus sp.	11
Sciaenops ocellata	11, 12
Pomacanthidae	
Holacanthus bermudensis	3
H. ciliaris	3
Pomacentridae	
Abudefduf saxatilis	3
Scaridae	
Nicholsina usta	3
Scarus guacamaia	3
S. coeruleus	3
Sparisoma (chrysopterum or *rubripinne)*	3 (as *S. flavescens*)
Gobiidae	
Microgobius gulosus	6
Acanthuridae	
Acanthurus coeruleus	3
Trichiuridae	
Trichiurus lepturus	7*
Scorpaenidae	
Scorpaena sp.	3
Bothidae	
Syacium micrurum	3
Balistidae	
Balistes capriscus	10, 11
Monacanthus ciliatus	3
Ostraciidae	
Lactophrys bicaudalis	3
Diodontidae	
Chilomycterus atinga	3
Diodon hystrix	3
Diodon sp.	6

Total: 55 species
* = fish that may have been killed by fishermen.

ACKNOWLEDGEMENTS

We would like to thank Eustice

Parnelle and Ross Wilcox of the Florida Power and Light Corporation for providing water temperatures from plants in the Tampa Bay and Indian River study areas, respectively. Mr. Shuler Massey kindly provided water temperature data from the Vero Beach municipal power plant. Mr. Charles Gollnick of the Vero Beach Recreation Department kindly provided Vero Beach surf temperatures. George Kulczycki, Phil Hastings, Jon Dodrill, David Mook and Coddy Williams took water temperature data and related valuable observations from the Indian River lagoon. Brian Barnett of the Florida Game and Freshwater Fish Commission and Ranger Allen Hoffacker of the Florida Department of Natural Resources both provided invaluable comments and observations on fish kills in Indian River and St. Lucie counties, respectively. We would like to thank George Henderson, Dannie Hensley, Mark Leiby, James Seagle, Gregory Smith all of the Florida Department of Natural Resources Marine Research Laboratory, St. Petersburg and Robert Jones of the Harbor Branch Foundation for their constructive comments on the manuscript.

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